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ABSTRACT

Discussed are how a free choice environment can be established in the classroom, the motivational advantages to including free choice in an enrichment program, and how implementing a free choice environment can serve as a teacher training tool. Several free choice studies are described. In one such study, a free choice situation was set up in three regular fifth-grade classrooms as an aid to instruction. In two classes free choice was combined with direct instruction in scientific reasoning; in the third class, free choice alone was presented. It was found that free choice combined with instruction was more effective than free choice alone in teaching scientific reasoning. (MH)

FREE CHOICE EXPERIENCES:

HOW DO THEY HELP CHILDREN LEARN?*

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Abstract

Hunt's theory of intrinsic motivation and the open education movement suggest that student choice is an important variable in instruction. Piagetian theory emphasizes the importance of interactive experiences and exposure to materials as opposed to direct instruction. In this study, interactive free choice learning experiences are compared to and combined with the lecture demonstration approach. The goal of both forms of instruction was to teach children to criticize and control experiments.

The lecture demonstration approach without opportunities for free choice was superior to free choice alone or free choice combined with the lecture demonstration approach in teaching students to criticize experiments. Lecture demonstration followed by free choice was superior to free choice followed by lecture demonstration, and to free choice combined with lecture demonstration in teaching students to design controlled experiments. Results suggest that ability to criticize experiments is a necessary condition for acquiring the ability to design controlled experiments.

Contrary to some of Piaget's statements and to recent research (Kuhn & Angelev, 1976), this study suggests that instruction combined with exposure to materials is more effective than exposure alone in fostering ability to criticize and control experiments. Results suggest that free choice is an effective instructional tool only after students have some familiarity with the goals of instruction. That is, students who are able to criticize experiments can learn to design controlled experiments from a free choice program.

Introduction

Student participation in decisions about their own instruction has been of interest to many investigators. Hunt (1965) in describing the role of intrinsic motivation in learning proposed that the best person to determine the match between task difficulty and learner characteristics would be the learner himself. Teachers who report succeeding in circumstances which most educators describe as hopeless often cite student choice as their primary educational tool (Holt, 1964; Daniels, 1971; Kohl, 1969). The open education movement is based, to a large extent, on student choice, but little research justifies this procedure.

Research on free choice in learning suggests that adults are better than children at selecting optimum experiences (Mager & Clark, 1963; Blackwell, Fuentes, & Fisher, Note 1). In contrast, Atkinson (1976) found that computer assisted drill sequences based on perfect memory for the adult subject's history are better than subject selected sequences. Several studies suggest that subjects learn more about materials that they choose (Dorsel, 1975; Clifford, 1973). Even for older subjects, performance on some tasks, such as planning a four-minute prose study session is better when determined by the experimenter than when designed by the subject (e.g., Dorsel, 1975). The hypothesis in this study is that subjects are better at planning their own learning experiences when they understand the demands of the task. Thus, performance is better for more experienced subjects and for familiar as opposed to unfamiliar tasks.

Piaget has popularized the notion that certain types of learning are not amenable to direct instruction. Piaget has emphasized the importance of exposure to materials rather than direct instruction. He says (1970):

> Interest is nothing other than the dynamic aspect of assimilation, . . . When the active school requires

> that students' effort should come from the student himself instead of being imposed . . . it is simply asking that the laws of all intelligence should be respected. (P. 158)

Commenting on the effectiveness of a classroom demonstration of controlling variables, Piaget said, "It would be completely useless, the child must discover it for himself." (Quoted by Hall, 1970) Piaget clearly believes that direct experience is important in learning.

Research on the advantages of direct instruction as opposed to exposure to materials is controversial. Several researchers have demonstrated that exposure can be effective (e.g., Morf, Smedslund, Vinh-Bang, & Wohlwill, 1959; Kuhn & Angelev, 1976). In addition, Kuhn and Angelev suggest that exposure is more successful than demonstration, yet the demonstration was <u>in addition</u> to the exposure. Thus, it appears that the demonstration actually hindered performance, a possible explanation for this result is discussed below. A number of studies have demonstrated that student progress is no worse in innovative programs without direct teaching like USMES (Shaun, 1976), or Community for Alternatives (Weber, note 2) than in traditional programs.

The hypothesis of the study described in this paper is that direct instruction activates appropriate schemes (as defined by Piaget) while exposure allows the subject to coordinate these schemes. Thus, direct instruction and exposure affect performance but not competence (developmental level). The direct instruction employed in this study consisted of eight lecture demonstration sessions. Exposure consisted of 12 free choice session during which subjects were allowed to choose the equipment they wished to use.

The subject matter chosen for this investigation is scientific reasoning ability. In particular, the ability to recognize variables, criticize experiments, and employ experimental design. Inhelder and Piaget (1958) have described the development of scientific reasoning during adolescence as proceeding from concrete to formal thought. A summary of research related to Inhelder and Piaget's work indicated that few children reach the formal stage and that attempts to teach scientific reasoning have been generally unsuccessful (Levine & Linn, in press). A number of studies have suggested that students learn to criticize experiments before they learn to design controlled experiments (Wollman, in press; Levine and Linn, in press).

We hypothesized that lecture demonstrations of how to control variables would activate schemes in most 12 year old subjects which would allow subjects to criticize experiments. Free choice experiments would permit students to coordinate schemes by providing the opportunity to select intellectually meaningful experiences resulting in the ability to control experiments.

Treatment

In our previous work we have developed the Free Choice Environment (FCE) which allows students to choose their learning experiences (Linn, Chen & Thier, 1976; in press). For the present study a direct intervention procedure was also developed.

Free Choice Environment - Over 40 science activities were designed (see Figure 1). For each activity, specific instructions and apparatus for one experiment were given. Each activity can be used in a variety of ways. All subjects carry out the suggested experiment first. We anticipate that subjects will adapt the activity to their own intellectual level when they choose a challenge. Subjects are encouraged to use the same apparatus to solve one or more "challenges" for which no solution is given (see Figure 1). There are

three challenges which generally range from further exploration of the apparatus to designing and setting up a series of controlled experiments. Students are also invited to invent their own challenges.

Insert Figure 1

about here

Earlier research (Linn, et. al., 1976; in press) revealed that this format was effective in (1) providing enough information to get students to explore the apparatus, and (2) providing opportunities for students to work at a variety of intellectual levels.

The free choice program consisted of 12 one-hour classes. Students came to a special room in groups of twenty. There was one adult supervisor to help with apparatus and supervise. No direct teaching was done. The supervisor answered questions by referring to the activity directions.

Direct Intervention - A teaching program was devised to explain the concepts of scientific reasoning. The lecture-demonstration approach was used to teach students to name variables, criticize experiments, and design controlled experiments. Students were asked to propose experiments and criticize experiments proposed by others. The direct intervention program consisted of eight 15-minute classes. As in the free choice program, students came to a special room in groups of 20 to participate in the intervention.

Procedure

All subjects received both free choice and intervention. The independent variable was the way free choice and intervention were combined.

Each of the three instructional programs consisted of two three-week sessions separated by a three-week break. The programs were:

1. Simultaneous Intervention and Free Choice. Students received intervention interspersed with free choice during the first session and no treatment during the second session.
2. Free Choice-Intervention. Students received free choice only during the first session and intervention only during the second session.
3. Intervention-Free Choice. Students received intervention only during the first session and free choice only during the second session.

Subjects

There were 21 girls and 39 boys from the 150 students enrolled in sixth grade in a racially and economically-mixed public school. Subjects were selected by teachers from those who volunteered to participate in science. They were assigned to the three 20 student groups at random.

Evaluation of Programs

The dependent variable was performance on scientific reasoning tasks given at various points. Each task required that subjects criticize experiments and design controlled experiments.

Pretest. The Pendulum Task adapted from Inhelder and Piaget (1958) by Tuddenham (1970) was used as a pretest.

Session One Posttest. Inhelder and Piaget's (1958) Bending Rods task was used as a Session One posttest. Subjects were asked to design and criticize experiments for each of the five variables (length of rod, material of rod, cross-section of rod, thickness of rod, and amount of weight hung on rod).

Session One Delayed Posttest. The Ramp Task developed by Linn and Levine (Note 3) was used as a delayed posttest. This task involved three

variables: weight of sphere, height of release, and size of target. Subjects were asked to design and criticize experiments for the weight variable.

Session Two Posttest. The Springs Task developed by Linn (Note 4) was used as a final posttest. Subjects were asked to design and criticize experiments for three of the five variables: diameter of spring, weight hung from spring, and thickness of the wire. The springs also differed in length and material.

Scoring. Criticizing questions were scored as correct if the subject indicated which variable was uncontrolled and described how to improve the experiment. Controlling questions were scored as correct if the subject set up a controlled experiment and justified it by saying that it was fair, equal, necessary to answer the question, or all but the variable being investigated were the same. Details of scoring for each task were given elsewhere: Pendulum (Linn, in press); Ramp (Linn & Levine, Note 3); Bending Rods (Linn, et. al., 1975); and Springs (Linn, Note 4).

Results and Discussion

In this section we will describe the operation of the program, the reliability and validity of the measures of scientific reasoning, and student performance on the measures of scientific reasoning.

Program Operation

Nearly all students indicated that they enjoyed the program and would recommend it to a friend on questionnaires administered twice during each session. Students attended an average of six free choice sessions as recorded by the leader (this was probably underestimated). Attendance figures were similar for the three groups. The mean number of activity sheets (reports on activity and any challenges) turned in varied considerably across groups. The Simultaneous group turned in an average of 9.8 sheets compared to 8.0 for the Free Choice-Intervention group and 4.9 for the Intervention-Free Choice

group (ANOVA significant p < .01). Since attendance figures were similar, we conclude that the Intervention-Free Choice group averaged more time spent on each individual activity. Similar to previous studies (Linn, Chen, and Thier, in press; Linn, Note 5), the most popular activities involved familiar variables and had simple directions (e.g., bouncing balls, map coloring, acid base testing, and tipping wooden rafts). The least popular activities were either complicated (e.g., using rubber band powered propellors to wind up string) or involved unfamiliar variables (e.g., determining which of three sealed boxes had the same shape inside).

Both leaders and observers noted that subjects who had the intervention were more task oriented during the free choice program. This is consistent with results of other studies (e.g., Wollman and Chen [Note 6] reported that there were more behavior problems in groups which were not given any cognitive-based instruction).

Intervention Program

Close to 80% of the subjects attended all eight intervention lessons. The Free Choice-Intervention group expressed dissatisfaction with the intervention because they weren't allowed to do their own activities and indicated that they preferred free choice. At each lesson, subjects engaged in serious discussions of the activities that were demonstrated.

Reliability of Tasks

All the tests were untimed interviews. The average intercorrelation between the tests within groups was .49, indicating that they measure similar abilities.

Tuddenham (1970) reports that his Pendulum task is a reliable measure. Case (Note 7) reports that Bending Rods and Spinning Wheels correlate .79. Linn and Levine (Note 3) report that the Ramp questions correlate .65. For the three groups, Springs has an average split half reliability of .51.

While not high, these reliabilities are satisfactory for assessing group differences. They are typical of reliabilities for short tests (the longest test had ten items), administered to groups of similar age and ability (restricted range). Since low reliability reduces the likelihood of finding group differences, any observed differences would be intensified with more reliable measures.

Validity of Tasks

All tasks used in this study have content validity in that they ask students to respond to or perform experiments. All the tasks were either developed by Piaget to measure scientific reasoning or were direct translations of Piagetian measures using new apparatus. Many researchers have used these tasks to measure scientific reasoning (Levine & Linn, in press).

Thus, researchers agree that the tasks measure the same construct. Since the average intercorrelation of the various tasks is .49, it appears that the construct they measure is influenced by specific factors for subjects of the same age and general ability. Possible influences are discussed elsewhere (Levine & Linn, in press).

Outcome of Logical Thinking Measures

The percentage of subjects correctly answering each set of questions on each task is given in Table 1. There were no consistent sex differences.

Insert Table 1

about here

Baseline (Pendulum). No significant group effect was found using the Kruskal-Wallis ANOVA test ($\chi^2 = 1.07$, $p < .58$), indicating that the three groups were of comparable ability prior to the educational programs.

Session One Posttest (Bending Rods). No significant group effect was found for controlling ($\chi^2 = 1.68$, $p < .43$) but a significant group effect was found for criticizing ($\chi^2 = 6.02$, $p < .05$). Closer inspection of the data shows that the Intervention-Free Choice program was superior to the Free Choice-Intervention program ($t = 24$, $p < .02$). These data indicate that the educational programs had no effect on ability to control variables, but that the Intervention alone (Session One of the Intervention-Free Choice) was superior to the Free Choice alone (Session One of the Free Choice-Intervention program) in fostering ability to criticize experiments.

Session One Delayed Posttest (Ramp). Three weeks after the first session, subjects were asked to criticize and control variables in an experiment with three variables. The pretest and this delayed posttest each involved three variables while the Session One and Session Two posttest each involved five variables. The three variable tests were easier than the five variable tests for all groups, consistent with previous research (Wozny and Cox, Note 8). The three variable delayed posttest exaggerated the differences between the groups and showed a significant main effect for groups on controlling three variables ($\chi^2 = 9.02$, $p < .01$) as well as criticizing ($\chi^2 = 7$, $p < .05$). Closer inspection indicated that, for controlling, Free-Choice-Intervention was significantly better than either of the other programs ($t = 2.6$, $p < .01$; $t = 2.4$, $p < .02$). For criticizing Free Choice-Intervention was superior to Intervention-Free Choice ($t = 2.7$, $p < .01$).

Session Two Posttest (Springs). A significant group effect was found for controlling variables ($\chi^2 = 5.9$, $p < .05$), but there is no effect for criticizing experiments ($\chi^2 = .42$, $p <.81$). Inspection of responses to the criticizing experiments questions indicated that all subjects improved over their pretest ability on criticizing and that the Intervention-Free Choice group performed slightly better than the other groups. It appears that all

the programs resulted in increased ability to recognize uncontrolled experiments but that only the Intervention-Free Choice program affected ability to design controlled experiments. Closer inspection of the data revealed that, for controlling, Intervention-Free Choice was superior to Free Choice-Intervention ($t = 2.5$, $p < .01$).

Relationship Between Criticizing and Controlling. Examination of contingency tables must be tempered with the understanding that the test reliabilities are not overwhelmingly high. Table 2 shows the relationship between controlling and criticizing.

Insert Table 2

about here

Of the subjects who were able to control on the final posttest, only two were unable to criticize on the Session One posttest, while 19 subjects were able to criticize but not control. On the final posttest, all but two subjects who could control were able to criticize, but 16 subjects who were able to criticize could not control (McNemar's test $p < .001$).

Thus, criticizing appears to be necessary but not sufficient for controlling. Even in the Intervention-Free Choice group, only 53% of the subjects controlled the experiments on the Session Two posttest, however, 89% of the subjects in this group correctly controlled two out of three experiments on the final posttest. Additionally, 86% of the total sample was able to correctly criticize two or more experiments on the final posttest. Thus the Intervention program was effective in teaching most of the subjects to criticize experiments and the Intervention followed by Free Choice taught most subjects to control variables in two out of three experiments.

Summary and Conclusions

A comparison of three educational programs, each of which included the same components was carried out to determine the optimal combination of intervention and free choice for teaching children certain aspects of scientific reasoning skill. The results confirm the hypothesis that subjects are most likely to profit from a free choice program when they have had intervention sessions to activate the schemes needed for the task. The evidence is:

1. There is a significant main effect for program on criticizing three variables and on controlling three variables after session one. There is a significant main effect for program on controlling five variables after session two;
2. The Free Choice-Intervention group is superior to the Intervention-Free Choice group on criticizing with three and five variables, and controlling with three variables after session one, indicating that Intervention alone is superior to Free Choice alone.
3. For controlling experiments with three variables Intervention is significantly better than Free Choice alone or Intervention plus Free Choice.
4. In controlling with five variables, Intervention plus Free Choice is superior to Free Choice plus Intervention.

It should be noted that the success of the Intervention-Free Choice program is consistent with the findings of our first study (Linn et. al., 1976) where we compared our treated group to subjects who had no training. In this study, students learned to recognize variables but not to control experiments from a classroom program based on the Science Curriculum

Improvement Study materials and learned to control from the classroom program followed by a free choice program. Whereas the intervention in our first study consisted of 18 one-hour sessions, in the present study it consisted of eight 15-minute sessions. The work of Seigler, Liebert & Liebert (1973) also suggests the importance of a rule plus example approach for teaching students to do pendulum problems.

Clearly, the mechanism involved in "activation of schemes" is not defined by this study. Clarification will be sought by considering other theoretical perspectives. Several theoretical perspectives are relevant to the findings of this study. Of particular importance are (1) Ausabel's theory of meaningful verbal learning, (2) the learning cycle proposed by Karplus, (3) Piaget's theory of equilibration, and (4) Pascual-Leone's Neo-Piagetian theory.

Ausabel's theory of meaningful verbal learning is compatible with these results, but does not really add any information. Ausabel's definition of an advance organizer is vague - something that facilitates learning new material. His examples are primarily outlines or summaries to facilitate learning from prose in adults. Perhaps young children need a different kind of organizer. Since children, according to Piaget, are concrete they may need concrete organizers. Also, verbal organizers were not studied so we don't know that they would not work. Other studies indicate that this is unlikely (e.g., Hawley, 1976). The intervention sessions provide a concrete illustration of the concept which the students are to learn.

Karplus (1975) has proposed a learning cycle to combine apparatus-based experiences with direct instruction. Karplus conceives of the instruction as inventing categories rather than activating schemes, but these again may be different names for the same phenomena. He proposes that direct instruction

be interspersed with exploratory sessions. The Simultaneous condition is closest to an application of the learning cycle and should be the most effective from this theoretical perspective. The Invention-Free Choice program is consistent with the learning cycle in that instruction precedes free choice but the intervention sequence is longer than Karplus would recommend.

Piaget has argued that concrete operational thinkers are limited by real results rather than being able to imagine all possible results. Previous studies have suggested that subjects in the free choice environment behave like concrete thinkers (Linn, et al., in press) and performance in the present study was similar. The intervention appears to activate schemes which enable subjects to carefully check all the relevant variables to see that they are controlled. With this background, subjects appear to coordinate the schemes and design controlled experiments when allowed to manipulate their own apparatus in the free choice program. As hypothesized, rather than helping subjects go beyond "real" results (gain in competence), it appears that during the intervention subjects learn to systematically check all the observable variables (change in performance).

It remains to clarify why the Simultaneous program was not more effective than Free Choice-Intervention since both Piagetian theory and the Karplus Learning Cycle suggest that is should be at least as effective as Intervention-Free Choice. One explanation is that the task structure presented in the Intervention might conflict with the structure generated by the learner during Free Choice, creating a conflict rather than a higher level equilibrium. This might also account for findings of Kuhn and Angelev (1976).

Pascual-Leone (1970) has proposed a neo-Piagetian developmental theory based on age-related changes in mental capacity. It may be that the intervention program helps subjects develop problem-solving strategies which involve less mental capacity (e.g., Scardamalia, in press).

Results of the present study are consistent with Piagetian and neo-Piagetian developmental theories, although one would expect better performance in the Simultaneous condition from these viewpoints. As predicted by Piaget, the direct intervention alone did not teach children to design controlled experiments. The results support the instructional theory of Ausabel and they extend these ideas to the area of apparatus-based learning and free choice. Rather than providing advance organizers in the sense of an Ausabelian preview or summary of the instruction, however, direct teaching of strategies was necessary to help subjects learn to design experiments.

These results have some interesting implications for free choice programs, open education, and informal learning. It appears that learning in these situations is far more likely to take place if the learner has been given a general structure or alerted to the salient features of the learning situation. The results suggest that Hunt's theory of intrinsic motivation may be, at best, less general than anticipated (Hunt, 1965). Free Choice alone was clearly less effective than direct instruction, indicating that even if students did choose intellectually meaningful experiences, they could have learned more from experiences provided by the teacher. An important finding, however, is that subjects did profit from free choice experiences after they had received direct instruction. This finding suggests that subjects need some guidance before they are likely to choose experiences which will help them learn. In this study, subjects only profit from free choice when they are able to criticize experiments. Also, students who have received direct instruction are more task oriented during learning, indicating that structure facilitates the success of a free choice program. Examinations of the work of Daniels (1970) and Holt (1964) indicate that they combined direct instruction with student choice. The Mager and Clark (1963) finding that

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Table 1

Percentage of Subjects Successful
On Each Evaluation Measure

Group	Free Choice-Intervention		Simultaneous		Intervention-Free Choice	
	N	%	N	%	N	%
Pretest	20	35	19	37	20	45
Session I Posttest						
Criticizing	20	40	19	58	20	75*
Controlling	20	25	19	32	20	35
Session I Delayed Posttest						
Criticizing	19	63	19	52	20	90*
Controlling	19	52	19	37	20	90**
Session II Posttest						
Criticizing	18	50	19	47	19	74
Controlling	18	17	19	26	19	53*

*Probability of differences between groups occurring by chance < .05
**Probability of differences between groups occurring by chance < .01

Table 2

Relationship Between Criticizing and Controlling

		Free Choice-Intervention		Simultaneous		Intervention-Free Choice	
Session I Criticizing	Pass	5	3	9	2	5	9
	Fail	10	0	5	3	4	1
Final Posttest Criticizing	Pass	6	3	5	4	5	9
	Fail	9	0	9	1	4	1
		Fail	Pass	Fail	Pass	Fail	Pass
		Final Posttest Controlling		Final Posttest Controlling		Final Posttest Controlling	

Figure 1.

FLYING OBJECTS

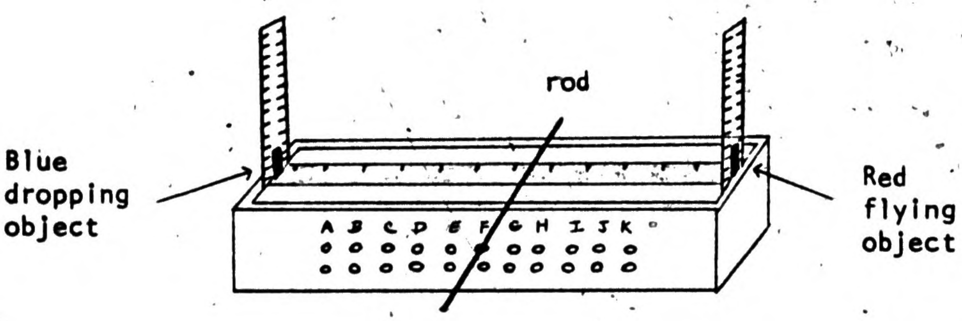
ACTIVITY: Find two ways to get the red object to fly to the top of the shaft.

MATERIALS

Flying object box
6 - 20 gram weights
Red flying object
Blue dropping object

DIRECTIONS

1. Set up the flying object system as shown.



2. Put one weight in the blue dropping object. What is the highest you can get the red flying object to go? _____ centimeters

3. Place another weight in the blue dropping object. What is the highest you can get the object to go now? _____ centimeters. The number of weights placed in the dropping object is one variable which affects how high the red object is hurled.

4. Continue experimenting with other variables until you find two ways to get the flying object to the top of the shaft.

5. List all the variables which you found influenced how high the red object was hurled.______________________________

____

____

FLYING OBJECTS CHALLENGE #1: Get the red object to fly exactly half the height from which the blue object is dropped.

Describe how you solved the challenge.

FLYING OBJECTS CHALLENGE #2: Make the red object go the same distance with 3 weights as with 1 weight. How much weight did you put in the blue object each time? ______________________

FLYING OBJECTS CHALLENGE #3: How many different positions of the rod can you use to get the red object to rise 15 cm?

Describe your solution to the challenge.